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THE GENERATION OF ELECTRICAL OSCILLATIONS IN CADMIUM SULFIDE MONOCRYSTALS

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THE GENERATION OF ELECTRICAL OSCILLATIONS IN CADMIUM SULFIDE MONOCRYSTALS

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ABSTRACT

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Results of tests on the appearance of electric oscillations in cadmium sulfide monocrystals show that irradiation of the crystals with infrared light affects appearance, form and amplitude of current oscillations. Two types of crystals result: those with linear volt-ampere characteristics, and those with saturable volt-ampere characteristics. Author

The properties of cadmium sulfide monocrystal showing oscillation of the photocurrent have long been known. It is mentioned in works of other researchers, or in short announcements already published (refs. 1, 2, 3 and 4). It has been established that this oscillation is possible when the proper constant tension is applied to a crystal stimulated with light with definite intensity. The generation of electric vibrations in the dark appear in stronger electrical fields and lower temperature (ref. 4). Under better selected conditions, the vibrations can be unceasing periodic with frequency within the limits of 0.1 to several hundred "cps." According to references 2 and 4, for the current /5*

*Numbers given in the margin indicate the pagination in the original foreign text.

oscillation in the crystal it is essential to have the presence of a nonlinear volt-ampere characteristic and the proper corresponding condition in the electrode layers.

Similar generations have been observed in other semiconductors, such as CdSe (refs. 2, 5 and 6), Ge (ref. 7) and Si (ref. 8). Similar in nature to CdS are the electric vibrations in CdSe. The present publication presents the results of further studying the processes of the generation of electrical vibrations in CdS monocrystals. Some basic dependencies are established which characterize the phenomenon, and the methods of working with the crystals in such a way that they can always show generation are described. Some possibilities for the practical utilization of the phenomenon are discussed.

Results of the Measurements

Monocrystals with a length of 1-7 mm obtained by Frerick's method were used. The electrodes were applied at few mm on one of the surfaces of the crystal through cathode dusting (Au, Cu), evaporation in vacuum (Au, Cu, In) or through lubrication (Ga). The samples were subjected to tension of 0-800 V. The crystals could be illuminated simultaneously with extinguishing infrared light or with stimulating light obtained with the proper monochromator. According to some previous works (refs. 2, 3 and 4) important factors in observing the /6 phenomenon are the electric field and the stimulating light, which affect the frequency, amplitude and form of the generations. However, we established that this plays a very essential and special role in the studied phenomenon. A bigger part of the generating crystals need irradiation with infrared light, which causes generation. In the remaining part of the generating crystals, oscillations without infrared light appear only with small intensity of the stimulating light, or in the dark. With stronger illumination, even they need infrared light.

It should be emphasized that the infrared action should not be treated only as a factor which (because of its extinguishing action) decreases the number of free electrons, thus acting contrary to the stimulating light. Tests show that if in a given current through the crystal and in the presence of stimulating light and of infrared light, there is oscillation, then, with the same current but without infrared light obtained through corresponding reduction of the intensity of the visible light, there is no oscillation. Figure 1 shows the dependence of the oscillation frequency on the current through the crystal, in which the applied tension and intensity of the stimulating light are constant, and only the intensity is changeable. There is no oscillation as long as the infrared intensity is very strong.

From the given value of the intensity downward there appear oscillations with small amplitude and assymmetric form. With the decrease of infrared light, the frequency of the oscillations drops quickly, but their amplitude grows. A plateau is reached at which the frequency is not changed by the decrease in infrared light. Here the oscillations are most stable and most symmetric and have maximum amplitude. With the further decrease of infrared light, the

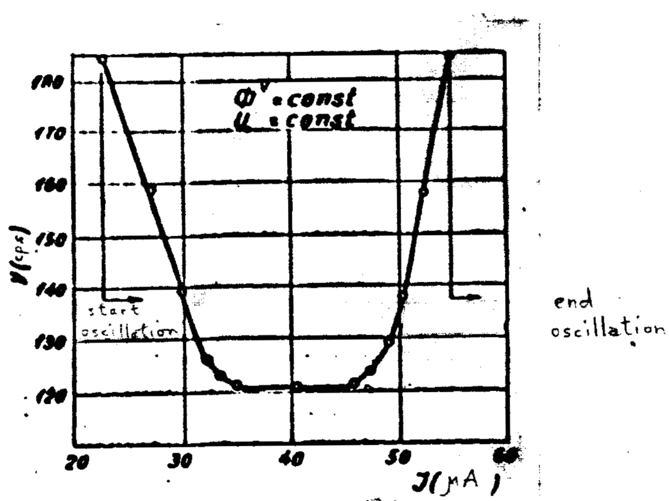

Figure 1

frequency of the oscillations grows again, the amplitude decreases, and the form is spoiled until the generations stop at the same frequency from which they have started.

It is clear that in constant intensity of the stimulating light there is an optimal infrared light value in which are obtained the most stable generations with maximum amplitude. Measuring showed that this optimal value is bigger when the intensity of the stimulating light at constant tension is stronger, and it is smaller if the applied tension is higher.

Infrared light causing the described action covers intervals with the wavelength between 800 and 1600 mm and with maximum action about 800-900 mm. This is exactly the light with well-expressed extinguishing action.

The dependence of the frequency of the oscillation on the intensity of the stimulating light with infrared illumination is linear (fig. 2), but the interval in which the intensity of the stimulating light can change is in this case very small. In a given intensity, the oscillations stop due to lack of infrared light. If simultaneously with the change of the stimulating light the infrared light is also changed so that it can always have optimal value, the interval in which the illumination can change without stopping the oscillation becomes significantly longer.

Figure 3 shows that the frequency of the oscillations decreases strongly as the tension increases. In order to change the tension in a long interval without interrupting the oscillations, and in order to maintain a definite form and maximum amplitude, the intensity of the infrared light should be changed, since its optimal value depends on the tension. The amplitude of the oscillation grows slightly with the increase of the tension (up to 3 times in the interval of 100-800 V).

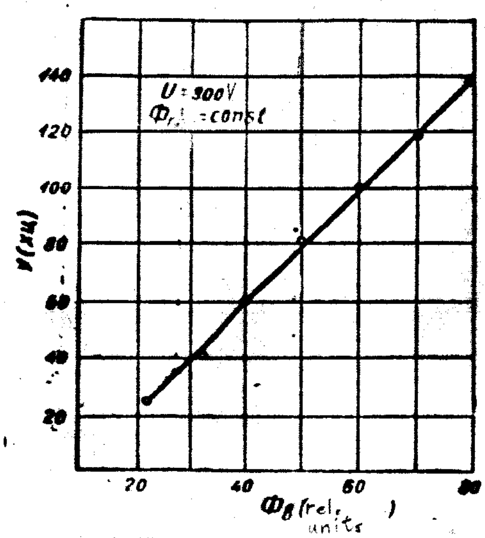

Figure 2

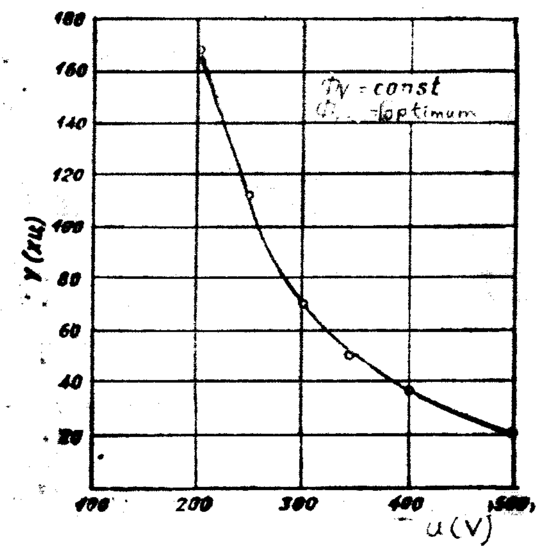

Figure 3

Since the illumination and tension act contrary upon the frequency of the oscillation, one and the same frequency can be obtained with most various correlations of the illumination and tension, and therefore in essentially different photocurrents through the crystal.

In all studied patterns it was established that higher tensions are necessary for the crystal to generate under stronger illumination.

Studies and research of the spectral dependence of the oscillation frequency have shown that during irradiation with monochromatic light with a wavelength in the area of the basic absorption of infrared light, stable oscillations /8 appear with a frequency which almost... and with the activity of the irradiation (fig. 4). Between 495 and 510 mm there exists a transitional area in which appear unstable and irregular form oscillations whose frequency decreases as the wavelength increases. When the crystal was illuminated with light from the area of the admixtured absorption, in none of the studied patterns was generation observed, even when the intensity of the light and the adequate photocurrent were very strong. This shows that the lack of generation in the last case should not be sought in the difference between the concentration of the conductors in illuminating with strongly absorbing light, and light with great wavelength. It seems very probable that for the appearance of generations, an essential part is played by the separate higher areas of the crystal's surface, which when stimulated and, in the volume of the crystal, move and oscillations do not appear. Other tests show that for the oscillation the side from which the crystal is illuminated is essential. If the illumination is done on the opposite side of the crystal (where electrodes are not present) it does not generate.

To check whether the presence of nonlinear voltampere characteristics is a necessary condition for generations, the characteristics of most of the tested patterns were measured. It was established that, depending on the kind of volt-ampere characteristic, all crystals studied by us can be divided into 2 groups.

In the first group are the crystals which, when in the dark or with small intensity of stimulating light show saturation of the current, at least in one of the directions of the applied tension. Almost all crystals with such saturating characteristics generate, but oscillations of the current are observed only in the direction in which saturation appears, beginning from the tension with which the saturation starts.

The second group of generating crystals have in all cases linear volt-ampere characteristics. This shows that the nonlinear characteristics of the volt-ampere is not a necessary condition for generation.

All dependencies given above for the frequency of the oscillation refer to the second group of crystals. The crystals of the first type compared with those of the second type show some differences. For example, the optimal value of infrared light does not depend on the application of tension upon the pattern, and the frequency of the oscillation does not decrease, but grows with the increase of the intensity of the stimulating light, as well as with the increase of the tension (fig. 5).

There are some reasons (refs. 9, 10 and 11) according to which the observed and studied oscillations of the currency in the crystals of the second group are caused by plasma-like processes which start under definite conditions in the semiconductors. If such processes really appear in the crystal, then in the crystal there should be created a strong field area, which moves the cathode to the anode, or pulses near an average situation. This leads to a change /9
in the distribution of the potential on the crystal, which should be certified through the drill method for measuring the potential.

The tests show that in the regime of oscillation ($r \approx 0.5$ cps) the /10
potential in almost every point of the crystal oscillates with the frequency of the currency vibrations, the amplitude of these oscillations being the greatest in some areas of the crystal's surface.

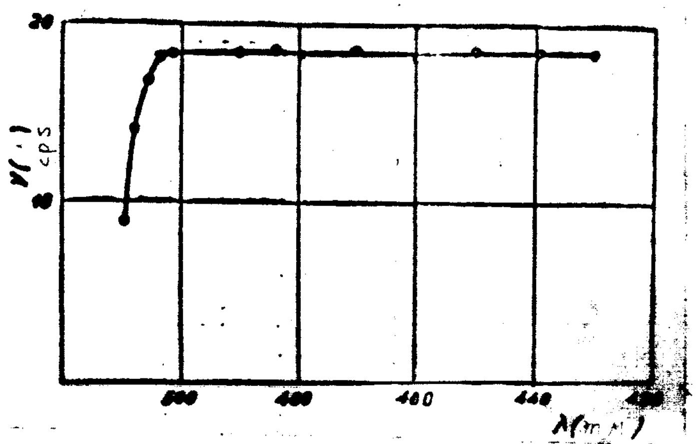

Figure 4

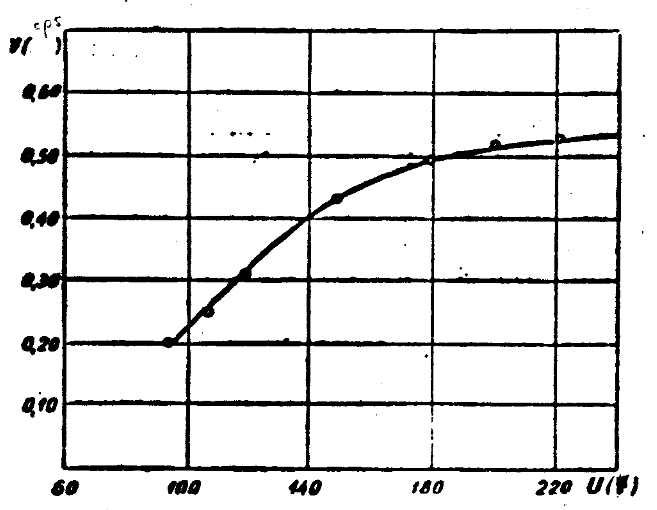

Figure 5

The measurings of the pace of the potential on the surface of the crystal of the second type shows the following: on the surface of all generating crystals there is at least one spot in which the change of the potential is much stronger than in the remaining part of the crystal. The strength of the field in this area can be from 5 to 100 times bigger than the average strength of the field in homogeneous crystal.

These results show that in order to have generations it is necessary to create on the crystal's surface a narrow homogeneous area upon which a significant part of the tension should fall. In order to check this, an attempt was made to create artificially nonhomogeneities upon the crystals. For this purpose, a narrow strip of the crystal's surface (about one hundred wide) was applied to Cu by cathode dusting, or through evaporation in vacuum for 10-20 seconds. In order for the copper to penetrate inside the crystal, the samples were heated in a hydrogen atmosphere at about 300°C for 15-25 minutes. All crystals thus treated began to generate. Studies of the potential distribution showed that on the spot where the copper was applied there exists an arc with strong field (fig. 6).

In the process of the work, in order to increase the crystals' sensitivity, they were heated in hydrogen atmosphere at 500°C for about 20 minutes. It was noticed that the percentage of the generating crystals was simultaneously increased (about 50 percent). It was established that there is a significant difference in the potential on the crystal's surface, before and after treatment in hydrogen atmosphere (fig. 7). The treatment in hydrogen leads to formation of nonhomogeneous areas due to the nonhomogeneous absorption, and the crystal becomes generating.

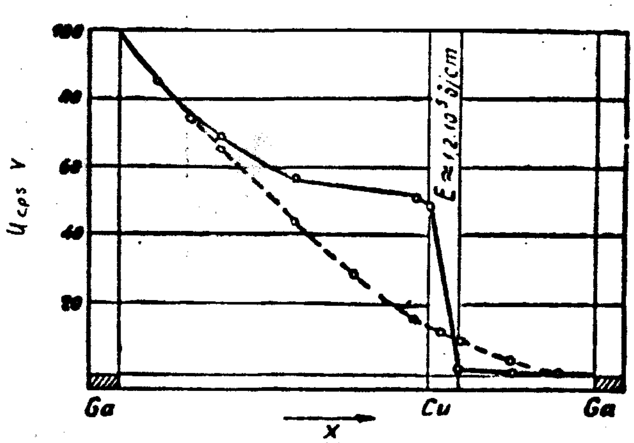

Figure 6

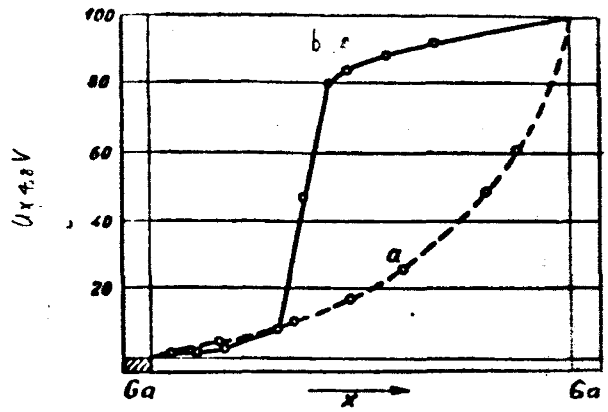

Figure 7

Based on the obtained regularities and properties of the generating monocrystals, it can be said that the studied phenomena are also of practical interest. It offers a chance for work directed toward the creation of simple and miniature photo-conducting generators for low frequencies, in which one can change the frequency and the amplitude of the current vibration. /11

The tests showed that the creation of an indicator for infrared light, or of preventative and guarding formation, can be a result of the application of the photo-conducting generator. For this purpose the generator is placed in such a critical regime that the smallest decrease in the intensity of the infrared light (for example, 5-10 percent), caused by infrared rays being crossed by moving object, leads to the beginning of generation and to strong sound signal if the crystal is connected with the corresponding sound system.

To explain the obtained results, one could use the theoretical deductions in references 9, 10 and 11. In our opinion, however, the complication of the processes, their great variety and the still insufficient experimental material do not give at present good possibilities for a satisfactory and sufficiently complete explanation.

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